UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Office of Administrator
Washington 25, D. C.

REPORT AND RECOMMENDATIONS
of the
SOILS, WATER AND FERTILIZER RESEARCH ADVISORY COMMITTEE
Developed at its Tenth Meeting
January 21-25, 1963
Phoenix and Tucson, Arizona

Soils, Water and Fertilizer Research Advisory Committee

William C. Ackermann, Chief, Illinois State Water Survey Division, Urbana, Illinois
Everett M. Barr, farmer and member State Soil and Water Conservation, Committee, Liberty, Nebraska
Arthur P. Bralley, Vice President, The American National Bank of Amarillo, Amarillo, Texas
G. M. Browning, Associate Director, Agriculture and Home Economics Experiment Station, Ames, Iowa Chairman
D. P. Fabrick, rancher and member State Water Conservation Board, Choteau, Montana
H. H. Harvill, Sr., farmer and Chairman of local Soil Conservation District, Humphrey, Arkansas
David H. Kistner, livestock farmer and member State Soil Conservation Committee, Loganville, Georgia
Robert McClellan, farmer and Soil Conservation District Director, Geneseo, New York
Robert Q. Parks, General Manager, Nitrogen Products Division, W. R. Grace and Company, Memphis, Tennessee
Floyd Root, wheat farmer and Chairman, Oregon Wheat Commission, Wasco, Oregon
James F. Sorensen, Consulting Civil Engineer and member National Reclamation Association Board of Directors, Visalia, California

Additional copies of this report may be requested from David J. Ward, Executive Secretary, Soils, Water and Fertilizer Research Advisory Committee, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

PREFACE

The Committee reviewed the Department's cooperative program of soils, water, and fertilizer research. It considered an annual Progress Report that includes a detailed presentation of Department activities as well as background information about related state experiment station and industry research and heard reports from Department specialists.

Dr. Robert Q. Parks was not able to attend the meeting to participate in the development of the report.

GENERAL COMMENTS AND RECOMMENDATIONS

The importance of soil and water resources to the present and future economic growth and development of the nation has been emphasized in recent Presidential messages, in reports by several Congressional committees, by governmental groups and by various national advisory committees. Private and public expenditures for water and related land resource development and management programs runs into the billions of dollars annually. This will need to be increased substantially in the future if we are to meet our water and related land resource needs. Research to provide quantitatively reliable information is essential for successful planning, development and management of these programs.

Strengthening Existing Programs. The Committee is pleased that some progress has been made in bringing research in existing facilities to a more effective operating level. Tomorrow's research cannot be done with yesterday's facilities and equipment, and we recommend continued emphasis on up-dating the research physical plant until work at present locations is at maximum operating efficiency.

New Facilities. We are encouraged that a few of the facilities and programs recommended in Senate Document 59 have been activated. But several of these units have not been funded at the level recommended and necessary for most effective operation. This should be done as soon as feasible. Additional new facilities are needed and should be provided as soon as possible, but activation of these should not delay adequate funding of existing units or the early completion of units now under construction.

Review Program Priorities. We recommend that the Department review the present priority for facilities and programs in Senate Document 59 and the current program of the Department to assure that the most important and urgent problems receive first attention regardless of whether they are immediate or long-term problems. Research on currently urgent problems in marginal and sub-marginal areas is needed, but we are concerned that not enough attention or support for research is going to prime agricultural areas which now and in the future will produce most of our food and fiber. The problems in these areas often appear less urgent and fail to generate interest and public support for research needed to guide both short and long-term programs.

Basic Research. There is no substitute for basic research to provide fundamental information for the efficient solution of applied problems. The Committee commends the Department for its effort to strengthen basic research and urges more emphasis in the quest for new knowledge.

Applied Research. But emphasis on basic research should not decrease emphasis on programs to assure the timely application of research findings for more effective resource conservation practices on farms of this country. Research results from the laboratory and field experiments must be tested, evaluated and adapted to field conditions to avoid costly mistakes and to encourage early application of new and improved practices.

Research at field stations of the Department and the State Agricultural Experiment Stations and field trials in cooperation with farmers are essential activities of the overall research effort. It appears to the committee that this phase of the program may need more support.

Support for Research. The research program of the Agricultural Research Service is supposed to provide quantitatively reliable information to guide resource conservation action programs of the Soil Conservation Service and the Agriculture Conservation Program. The Bureau of Reclamation, other Federal and State government agencies and many local groups also depend on the Department's research for information in developing their programs. It is unrealistic to expect the present research programs of the Department to furnish adequate information for such a large and complex program. We suggest the Department consider a method of arriving at the level of support for soil and water research based on the importance, size and complexity of the action programs being served. Increased expenditures for research to provide more adequate information to guide development programs is not a cost but a saving since the extra cost should be more than offset by lower program costs through more effective and efficient soil and water control practices.

Cooperation and Coordination. We commend the Department for its effort to bring about more inter-agency and interdisciplinary cooperation and coordination of research and action programs. In total, the national natural resource program is large and complex. It cuts across the interest and activity of many individuals, private groups and public agencies. We are encouraged that some progress is being made to avoid unnecessary duplication of effort and conflict of interest through a cooperative and coordinated approach. Much more can and must be done if our water and related land resources are developed and used to the greatest benefit of our entire society.

Research on Watershed Areas. The Committee is pleased to note that sizeable federal appropriations have been made in support of water related research, particularly in the field of pollution and saline water conversion. But we are concerned that essentially none of the increased appropriation was for research on problems in agriculture and forest watersheds where most of the nation's water supply originates, accumulates or runs off and is used by our population, our agriculture, and our industry. We believe the soil and water programs of the Department of Agriculture are of greater importance now and in the future and are concerned that funds for soil and water research on the nation's watersheds have not kept pace with the needs.

Support for Agricultural Research. We are also concerned that agriculture's share of federal funds for research has shrunk from 40 percent in 1940 to less than 2 percent in 1962. The Committee believes the present total research effort in agriculture will not provide adequate information to guide programs in the best interest of our entire society and for the present and future economic growth and development of the nation. We urge the support of the Department and Congress for more adequate support for agricultural research generally, since essentially all phases directly or indirectly influence soil and water conservation and use.

RECOMMENDATIONS ON CURRENT PROGRAM AND NEEDED RESEARCH

In recommending new or expanded research on problems listed in this section, the Committee recognizes that it is not its responsibility to delineate between research to be conducted within the Department and that to be conducted in cooperation with State Agricultural Experiment Stations, other research agencies, and industry. The recommendations made by the Committee are in terms of the importance of problems on which research is needed and in which the Department should participate.

WATERSHED ENGINEERING

Water and related land resource development and management programs are needed on 8,300 agriculture watersheds in this country. These watersheds are the source of our surface water supply - runoff from them fills our reservoirs for agriculture, municipal and industrial uses. The land within them furnishes the greatest part of the food and fiber for 185 million Americans. They provide outdoor recreation and fish and wildlife areas. Our growing population will depend on these watersheds for their future resource needs.

The upstream watersheds are the head waters and the key to successful resource development of our major river basins. Uncontrolled runoff from these areas causes floods on our lowlands. Unless properly treated, they produce sediment that pollutes our streams and depletes the capacity of our reservoirs.

Sedimentation in Relation to Watershed Development and Protection. Sediment is the largest single pollutant of the nation's streams and reservoirs. It damages fish and wildlife, reduces reservoir storage capacity, clogs highways and drainage ditches, fills stream channels causing increased flooding and adds to the cost of cleanup following floods and of removal from domestic and industrial water supplies. The source of sediment is erosion of land and stream channels in agricultural watersheds. Sediment control requires a variety of land treatments and mechanical control measures. Many factors such as the amount and intensity of rainfall, soil, steepness of slope, and type and amount of vegetation influence sediment production. Past research has provided information for present soil and water conservation programs, but the information is limited to a few conditions. Research should be expanded to obtain basic information on each factor that influences sediment production and an evaluation of control methods on bench-mark soils throughout the country. Emphasis should also be given to the development techniques and methods to transpose information from controlled experiments to field application on untreated areas.

The Sedimentation Laboratory is providing information for the southern Mississippi valley loess land resource area. Some research is in progress in 9 other land resource areas. This needs to be intensified and new work started in other parts of the country where sediment problems are significant. Stream bank erosion and channel cutting cause serious damage

to agricultural land. Stream channel stabilization studies are needed to prevent this loss and to decrease sediment production.

Reservoir silting is a problem in most water storage or regulating reservoirs. Additional studies are needed on the amount, density and distribution of reservoir sediment. There is essentially no information on the trap efficiency of flood water detention reservoirs and research to meet this need should be given high priority.

Hydrology and Water Resources of Agricultural Watersheds. Basic hydrologic data on runoff, water yields, profile storage and ground water recharge is inadequate and research should be expanded to provide quantitatively reliable information to guide resource development and management programs. Gross hydrologic data has been accumulated over a period of years by a number of groups. But many of these records have limited value in small watershed planning, since the effects of specific factors that affect runoff and erosion were not measured.

The need is for fundamental information to establish the inter-relationships between runoff and various land-use and management practices. This information is essential for sound watershed planning whether it be for flood control in one area or for water yield improvement in another area. Senate Document No. 59 recognized the need for major experimental watersheds in all 15 major land resource regions of the country, and recommended the early establishment of 6 such centers. Partial funding has been provided for 4 of these centers. First priority should be to bring these authorized centers to full operating strength. Centers recommended for the southeastern and northeastern regions should be activated as soon as feasible. Consideration should also be given to early establishment of centers in the northern plains area and the Pacific coastal area. The present effort of the hydrology laboratory should be strengthened to permit tabulation, analysis and interpretation of all hydrology records, to assure that full use is made of present information in developing programs on the 8,300 small watersheds that now need treatment. Also special emphasis should be given to the development of techniques and procedures for transposing information from research watersheds to ungauged watersheds.

Hydraulics of Irrigation, Drainage and Watershed Structures, Channels and Facilities. Water-control structures are an essential part of a water and related land resource program. They represent the largest part of the public and private cost for watershed, irrigation and drainage development programs. More research on the design of structures is needed to prevent the extra cost of over-design or failure of under-design. The research should be to establish principles and develop dimensionless designs which can be adapted to various site situations and size requirements on individual farms and in upstream watersheds.

Research is urgently needed to improve the hydraulic efficiency of trash guards for drop inlet and closed conduit spillways. In order to improve outlet and channel conditions, superior devices are needed for vortex

control and dissipation of energy at reservoir spillway and gated outlets. Improved flumes, weirs, gates, and rating sections are also needed for more accurate streamflow and water discharge measurement.

First priority should be to bring research at present locations to maximum operating efficiency. In addition the Conservation Structures Laboratory, the Irrigation Structures Laboratory and the Drainage Principles Laboratory recommended in Senate Document 59 are needed before this important research can be efficiently carried out.

Forest Watershed Management. All of the major rivers of the United States have headwaters in forests, associated range lands or alpine regions. More than half of the waterflow of the country originates in such areas. Whether this waterflow is beneficial or harmful, is well regulated, sustained flow of good quality or erratic and silt laden, depends on how the headwater lands are managed. We also depend on these lands for a variety of products and services.

The Committee was pleased to note from the report made by the Forest Service that real progress has been made in this area of work. But as with other areas, we are concerned that information is still inadequate for developing programs that will assure the best use of forest and related resources and still protect them to meet our future needs. The need is for more research on management of storm runoff, reduction of flood runoff, and erosion and sedimentation control. We are pleased the Forest Service, the Agricultural Research Service and other public and private groups are cooperating on problems of mutual interest on crop, forest and range lands and urge even closer cooperation and coordination in the future.

WATER MANAGEMENT

Agriculture has so far had first call on the nation's water supplies and has been the principal user of the land resources. This will not continue indefinitely. As pressures grow for increased industrial, recreational and urban use of water, agriculture increasingly will have to justify every acre foot of water it uses. We will have to balance agriculture needs against other demands, something that we haven't had to do in the past. We must strengthen our present efforts to assure greater efficiency of water use for agricultural purposes. And we must look for newer and better ways to develop additional sources of water.

Water and Wind Erosion Control. Almost unbelievable progress has been made in soil and water conservation in the last quarter century. The activity in 2900 soil conservation districts that now almost blanket the country, in addition to programs by many other public and private groups, has made this possible. Information from research of the Department and others has been invaluable in guiding these programs.

Although real progress has been made, the facts are that more acres remain to be treated than now have programs.

In addition, many of the treated acres must be re-examined and new and better control methods adopted, and other adjustments made to meet the changing needs of agriculture. The present research program should be expanded to provide reliable information on all factors affecting soil and water conservation.

More fundamental information is needed on the processes and mechanics of erosion, including items such as drop impact, soil disruption and movement in splash and water flow, freezing, thawing and snow melt, hydraulics of sheet and channel flow, surface sealing, soil characteristics related to erodibility, soil loss tolerances, and effects of surface roughness, vegetation, length and steepness of slope, and mechanical practices. Fundamental work of this type can be done best in existing laboratories, which should be brought to more effective operating levels, and additional facilities such as the Mechanics of Erosion Center as recommended in Senate Document No. 59. More emphasis is needed to test, evaluate and apply these principles to the wide range of climate, soil, topography, vegetative cover and management in the major land resource areas.

As basic information becomes available, more effort is needed to develop and adapt prediction equations in those areas where the results are now being used and extend and apply this procedure to areas where it has not been used.

Terraces, diversions and other mechanical practices do not fit some of the modern farming techniques and are limiting the use of these practices as important control measures. Effective erosion control cannot be accomplished without mechanical practices on millions of acres of sloping land which are now used and must be used in the future for the production of intertilled crops. High priority should be given to reevaluation of this phase of the program and to expand work so that these practices will be used more extensively. Field trials, in cooperation with farmers, are an effective approach to the solution of this problem and should be used more extensively.

Conservation of Water Supplies for Agricultural Use. The storage, conveyance and distribution of water for irrigation is notoriously inefficient. About 40 percent of the water diverted for irrigation purposes is lost by seepage, evaporation, use by non-beneficial plants and by wasteful runoff. Fall in water tables is increasing pumping cost, and there is danger of depletion over an appreciable area. A dependable and economical source of water is needed in some of the grazing areas.

More research is needed to develop principles, practices and equipment for the reduction of water losses, for the development of new water sources, and for the recharge of ground water. More research is needed on low-cost soil stabilants and sealants to decrease farm water conveyance losses, and to develop satisfactory methods for spreading chemicals to prevent evaporation from water surfaces. The laboratory and field stations at Tempe, Arizona; Twin Falls, Idaho; Prosser, Washington; and Weslaco, Texas are logical headquarters for this work.

More attention is needed to design procedures for developing adequate farm water supplies in the Coastal Plains area and in the northern range lands of Idaho and South Dakota. Ground water levels are being seriously lowered by pump irrigation and are particularly acute in the Southern High Plains and the central valley in California. Bushland, Texas and Fresno, California appear to be logical headquarters for an expanded program to study principles of ground water recharge.

Moisture Conservation on Crop and Range Land. Agricultural use of precipitation is very inefficient. Fallow systems store only 1 inch out of every 5 that falls. In the humid region about 50 percent of the rain that reaches the land is lost as evaporation from the soil's surface. Inefficient moisture storage and utilization is even greater on range land than on crop land. With the increasing demand for water, agriculture must do everything possible to use more efficiently its portion of the water supply.

The potential for more efficient use of water is almost unlimited. But it cannot be done until more fundamental information is available. More research is needed to provide basic information on the effect of soil, climate, land use, cover, tillage methods, field leveling, benching, water spreading and other soil and crop management practices on moisture conservation on crop, forest and range lands. These fundamental studies can be done best in existing locations such as Morris, Minnesota, Bushland, Texas and in laboratories at State Experiment Stations where cooperative work is now in progress. The application principles from basic research must be tested, evaluated and adapted to a wide range of field conditions. Support should be provided to assure that the work needed is done in each of the major land resource areas of the country.

Irrigation Design Principles, Requirements, Practices and Facilities. The agricultural economy of the West depends upon irrigation. Annual and seasonal droughts and humid areas have increased interest in irrigation, especially on high-valued crops. Irrigation has been practiced for centuries, but basic information to assure the most efficient use of water is not available. Basic research is needed on design of water application systems and efficiencies, water intake, percolation, root zone storage, evapotranspiration under irrigation conditions, numerical equations for prediction of evapotranspiration, fertilizer-water interactions, plant or other indicators of irrigation schedules, and other related problems. This type of research can best be accomplished by a central laboratory with scientists and engineers of many disciplines working together. The need for an irrigation center to provide this type of information was recognized in Senate Document No. 59.

There is need for more research on the hydraulics of irrigation structures, including the design of metering devices, turnouts, drops, field conveyance channels and underground pipeline systems, automatic water control gates, sprinkler nozzles, automatic water control devices and related pipe and elbow systems. The research should be directed to the development of principles and design criteria that are common to irrigation

systems regardless of location, soil, climate and crop conditions. These problems can best be solved in a central laboratory as recommended in Senate Document No. 59.

There is need for more information on the water requirement of crops, soil-water relations and crop response. Research of this type, to be most effective, must be done in the different soil-climate problem areas. The Atlantic and Gulf coastal plains, the Mississippi delta, North Lake States, Intermountain meadow areas, North Central plains, Snake River Valley, Columbia River basin, Southern plains and Salt River valley are areas where additional information is needed.

Drainage Principles, Requirements, Practices and Facilities for Protection of Crops and Soils. High water tables, flat poorly drained areas, hillside seeps and salting out in irrigated areas of the West limit crop production and reduce farming efficiency on millions of acres of land in the United States. Tile and ditch drainage have been practiced for centuries. Water management systems have been applied with varying degrees of success to some 140 million acres of wet lands in the United States.

Information from past and current research has made it possible to improve drainage methods, but there still is little or no information on the basic principles of moisture movement through many important soils. Not enough is known about water tolerance of different plants at different stages of development and under different climatic conditions. There is need for more research on the effect of long continued cultivation, heavy machinery and soil and crop management practices on the drainability of soils. Information of this type is needed for the design of more effective new drainage systems or for the renovation of existing systems, many of which are now inadequate because of initial faulty design or deterioration over time.

There still are areas in the country that are wet or completely flooded. There is need to evaluate the best future uses of these areas and to develop plans for their long-time effective use.

Basic drainage principles can best be established by a team of scientists and engineers of various disciplines working together with modern equipment in a central laboratory of the type recommended in Senate Document No. 59. Basic principles established under controlled laboratory conditions must also be tested and evaluated under a wide range of soil-climatic conditions found throughout the country. Studies of this type are needed in the major soil-climatic areas where drainage is a problem.

Control of Aquatic Weeds. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, irrigation and drainage systems. They annually transpire millions of acre feet of water which could be available for productive use. The Committee was pleased to note the progress that is being made in weed control of aquatic plants as reported by the Crops Research Division. The problems of controlling aquatic weeds

in irrigation canals, ponds, reservoirs, and lakes cover a wide range of conditions and additional research to develop the more effective control methods could result in substantial savings of water. More information is also needed on methods of control of undesirable plants, particularly in the western states.

SOIL MANAGEMENT

Soil Properties and Management in Relation to Land and Water Resources. Soil and water conservation practices developed by action agencies for use on farms depend on sound technical information. Many practices are being developed today without the benefit of essential fundamental information. Most conservation practices are affected by soil structure, but today we have no accepted method to quantitatively measure and evaluate this important soil property. Soil structure influences the movement of water into and through soils, the uptake of water by plants, the distribution of plant roots in the soil, the activity of soil microorganisms, and the efficient utilization of air, water and nutrients for plant production.

The fundamentals of soil structure formation must be understood before residue management systems, tillage methods and cropping systems can be developed that will improve and preserve soil tilth. Allocation of manpower to this area of work by the Department and State Agricultural Experiment Stations is larger than for any other area, emphasizing the importance of these problems. Current programs should be strengthened by updating existing facilities and more adequate support for staff and operating expenses. To help develop more basic information on the effect of soil structure and related tillage and management practices on plant growth and soil and water conservation, a Soil Tilth Research Center, as recommended in Senate Document No. 59, should be activated as soon as feasible. Work in this facility would not duplicate the current program but would permit more intensive study of these important problems by a team of scientists and engineers with specialized equipment for the control of temperature, moisture and other factors.

Soil, Water and Plant Relations. A better understanding of the soil-plant-water relationship is fundamental to future technological progress in agriculture water management. It is generally accepted that only 1 to 2 percent of the sun's energy is used by the plant to manufacture food. A portion of the remaining energy is used to evaporate water from the plant and soil. Since the heat budget cannot be violated, fundamental studies to better understand these relationships is essential to future technological progress in conservation of water and more efficient crop production. To make efficient progress in this extremely difficult area of work will take a team of scientists and engineers, working under carefully controlled conditions in a well-equipped laboratory similar to the Soil, Water, Plant Relations National Laboratory, as proposed in Senate Document No. 59. We urge that a facility such as this be provided as soon as feasible.

In addition to the work in a central facility, supplemental studies under natural environment are needed on problems such as the effect of soil,

plant and meteorological relations to the assimilation of carbon dioxide.

Saline, Sodic and Related Soil Problems. Salinity is a major problem in irrigated agriculture. Injurious concentration of salts causes damages on about 25 percent of the irrigated land in the arid west. Control of salinity and reclamation of salty soils involves many complex physical and chemical problems. The research program on saline and sodic soils at the Salinity Laboratory, Riverside, California, is outstanding and world famous. This laboratory, from the beginning, placed major emphasis on the development of basic principles. This should be continued.

Problems that need additional attention include the reactions between dissolved and absorbed constituents, structure and microbial relations, soil physical and chemical conditions in relation to plant growth and diagnostic techniques for salt affected soils. More research is also needed on salt tolerance of economic plants, plant-water relations, absorption processes, on distribution and effects in plants, and the influence of climate and adaphic factors on plant response.

The salinity problem varies widely under different soils and climatic conditions and should be expanded at field stations representative of the major problem areas. Examples of the kinds of studies that are needed include "water composition-and actions occurring when salt-affected soils are irrigated and drained" and "crop and soil management systems for various levels of salinity and sodium saturation of soils". More research is also needed to develop efficient methods of leaching to reclaim areas where the salt concentration now prevents efficient crop production.

Nutrition of Animals as Affected by Properties and Characteristics of Soils and Plants. Work at the U. S. Plant, Soil and Nutrition Laboratory at Ithaca, New York, and cooperative field and laboratory investigations with State Agricultural Experiment Stations and other groups has made an outstanding contribution to knowledge about relationships among soils, plants and animals. We are pleased to note that additional facilities and support have been provided sc that this central laboratory can more nearly perform the functions for which it was established.

The primary function of the central laboratory should be to work on basic principles, which can be done best with specialized facilities, and to expand cooperative work with State Agricultural Experiment Stations interested in the problems and where large animal facilities and laboratories are available. We recommend that full use be made of the cooperative approach for large animal work and that large animal facilities not be developed at the central laboratory.

Fertilizer Technology Investigations. American farmers spend 1-1/4 billion dollars annually for fertilizer. Tonnage of fertilizer used has increased rapidly in recent years, especially in the midwest area. It is reasonable to assume that this use will increase in the future.

Fertilizer technology research programs of the Department, TVA, and industry have made great strides in the development of more efficient fertilizer manufacturing processes, improvement in the quality of the product and ease with which it may be applied. This, along with a greater appreciation of the need and results to be expected, is responsible for the widespread and expanding use of plant food materials. However, there still are many fertilizer technology problems that need to be solved to assure continued advancements in this important industry.

It is estimated that industry devotes 600 professional man-years of research to this area. TVA has had a large fertilizer technology program for a number of years and soon will complete a 9 million dollar laboratory that will be devoted exclusively to this type of work.

Though, the Department's program, in the past and now, is small compared with industry and TVA programs, it has made outstanding contributions. It has pioneered in the development of new techniques, procedures and processes that now are used generally by the industry. Cooperation and coordination among the groups has been good and to the mutual benefit of the entire industry. But with the large research effort on fertilizer technology by industry and TVA, we suggest the Department review its program in this area and provide more adequate support if continued, or if the other groups are meeting the needs, discontinue this program and divert the support to other areas of work.

Soil-Machine Relationships. Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Tillage tools have remained essentially unchanged since their invention. Evidence exists to show that many unneeded and in some cases detrimental tillage operations are performed.

Intensive research is needed to determine the optimum tillage requirements, based on cost and crop response for various soils, climate and crop conditions. Special attention should be directed to the development of tillage practices such as mulch farming and plow-plant or similar methods that have been proven to be especially effective in the conservation of soil and water. Inconvenience of operation and decreased crop yields have limited widespread use of these practices. Basic studies in the laboratory and in the field are necessary to determine the factors responsible for the unfavorable response and for the development of techniques and procedures to overcome the factors limiting the potential use of practices that have desirable soil and water conservation features.

Planting and Fertilizing Operations and Equipment. Planting equipment now in use is characterized primarily by machines that will plant seed in accordance with traditional practices. Improved technology, including higher yielding crops and increased application of commercial fertilizers, has emphasized the need for more research to precisely define seedbed requirements for various crops in different areas of the country. Depth of cover, size of soil particles, degree of soil compaction, soil surface profile and row spacing are important problems that need additional attention.

ECONOMICS

Economics of Water and Land Use Development. The land, water and forest resources of the nation are vital to the continuing health, safety and economic well being of its citizens. National programs, through planning and coordination, should be directed at the conservation, development, and management of these resources to support a balanced and strong economy. To achieve this goal, economic research is essential to point up the efficiency of a program or a combination of programs along with alternative ways to achieve water and land resources conservation.

More attention is needed on regional analysis of (a) the quantity and quality of water supplies available for agricultural and non-agricultural uses, (b) projected agricultural and competing non-agriculture water requirements - considering population growth, urbanization, industrial expansion and projected demands for agriculture products, (c) economic values of water in agriculture as compared to non-agriculture uses to indicate allocations conducive to regional economic development, (d) cost of alternative means for directly increasing usable water supplies and enlarging the range of alternative water use patterns, and (e) possibilities for indirectly increasing available water supplies through more efficient agriculture use, the reduction of reservoir evaporation and the reduction of irrigation water conveyance losses from seepage or phreatophytes.

Successful conservation practices vary significantly by regions, different physical conditions and type of farming. An expanded economic research program is needed to provide basic information to guide programs of soil conservation districts, Bureau of Land Management and other public and private groups on soil and water conservation measures such as contour farming, strip cropping, and associated mechanical practices such as diversion of waterways. Information is also needed on land leveling and smoothing for drainage, and irrigation in the humid areas.